

Biotechnology and Biomimetics Opens New Routes to the Fabrication of Silica and Metal Oxide Semiconductors.

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We discovered that the specific proteins found in marine sponges that enzymatically produce silica (i.e., “silicateins”), catalyze and structurally direct the hydrolysis and polycondensation of the molecular precursors of such metal oxides as gallium oxide, titanium dioxide, and zinc oxide. These are the first reported examples of enzyme-catalyzed, nanostructure-directed synthesis of these materials – and the first such syntheses at low temperature and neutral pH. Interestingly, interaction with the template-like protein surface is capable of stabilizing polymorphs of these materials that otherwise are not normally observed at low temperatures. Thus, for example, nanocrystallites of anatase titanium dioxide and gamma-gallium oxide are formed on the protein at room temperature. Perhaps most remarkably, in some of these cases the interaction between the condensing metal oxide and the protein results in preferential alignment of the resulting nanocrystallites of the mineral, suggesting an epitaxial-like relationship between the mineral crystallite and specific functional groups on the templating protein surface. Recent results confirm our suspicions that the underlying protein has a crystalline structure capable of producing a repetitive crystalline template upon which the metal oxide may order.

Biomimickry is currently being used to catalyze and template the growth of various metal oxides. We are incorporating analogs of the critical amino acid residues found in silicatein’s catalytic active site, anchoring these functional groups (via self-assembled monolayers on gold) adjacent to one another to facilitate catalytic activity by the same mechanism exhibited by the enzyme. Results have shown that biomimetics of the active site in silicatein are capable of producing silica from alkoxide precursors at neutral pH.

We presently are attempting to extend the genetic engineering approach described above to identify and then harness the natural structure-directing determinants of the protein. Potential uses of this low-temperature, neutral pH route for nanostructure-directed synthesis are optics, electronics, sensors, and pharmaceuticals.